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# FIRE DETECTION IN ATRIUM BUILDINGS

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ABSTRACT

With advance of building-construction techniques and for more effective use of land, new forms of buildings such as ones with extended height, deeper underground floor levels or larger space have been or are being built in Japan in recent years. This also applies to atrium buildings having large well space, and besides the comfort and convenience they offer to occupants and visitors in the premises, their use tends to be more diversified as seen in similar structures such as large-scale exhibition hall and dome stadium.

While admitting merits and advantages of the atrium space, one should be aware on the other hand that there is a danger that it could become a big weak point in fire protection for the building premises. If a fire breaks out in the atrium, smoke rapidly spreads into upper floors through the atrium space, causing a serious hindrance in the way of occupants' escape from the premises. Therefore, it is necessary to detect a fire in its early stage and to facilitate fire suppression, for which an effective system configuration with fire detection and extinguishing systems must be planned for the atrium. This paper introduces the fire detection systems installed in the atrium buildings and typical examples of their installations in Japan.

## 1. Fire detection systems in atria

As compared with occupied spaces in ordinary buildings, the atrium has a much higher ceiling and far greater space volume. Therefore, even if conventional spot type smoke detectors or heat detectors are installed on the atrium ceiling, we can hardly expect their effect because smoke and heat generated from fire in its incipient stage are diluted to undetectable smoke density and airflow temperature levels before they reach the detectors. Furthermore, in the case of an atrium with its ceiling constructed with a transparent or semi-transparent material to admit natural light, the temperature in the space close to the atrium ceiling is high due to solar radiation and influence of the air conditioner and creates a hot zone, which might possibly prevent the updraft from the source of fire from reaching the ceiling. In view of these considerations including their maintenance and inspection the following fire detection systems have been installed for fire protection of the atrium buildings.

### (1) Projected beam type smoke detector

This detector monitors a space over a long distance and detects smoke in a wide range. Therefore, it can detect a fire in its early stage even if smoke spreads in the entire space.

1) Sensitivity and installation standard

The projected beam type smoke detector operates on obscuration of the beam by smoke. This obscuration is related to the beam length as per the Lambert-Beer Law, and accordingly the longer the distance is, the higher obscuration becomes in the same smoke density. Therefore, it is the considered necessary to adapt the sensitivity of the projected beam type smoke detector to a monitoring distance (beam length) and to review the installation standard which determines horizontal spacing between the detectors for effective and early detection of fire occurring in one supervisory zone. A number of fire tests have been conducted by fire research bodies to measure smoke distribution and densities near the ceiling surfaces. Fig.1 shows distribution of smoke from a smouldering wood fire generating little heat measured below the ceiling surface. Fig.2 shows results of the test indicating the relationship between monitoring distances and obscurations. From these test data it has been found that a fire can be well detected if the distance between the fire point and the detector beam is less than 7m. Accordingly, it has been decided that the space between the detectors shall not exceed 14m. The test data also indicated detector sensitivities of 30~60% as being appropriate for the monitoring distance of 29m, and 15~30% for the monitoring distance of 5m.

Based on these findings, the monitoring distances related to the sensitivities of the detectors have been determined as shown in Table 1.

As for siting of the detectors in the atria, it has been recommended to install two detectors, i.e. one above the other in spaces with a height of 20~60m, and three detectors, i.e. one each at the upper, intermediate and lower levels in spaces exceeding 60m in height.

2) Design

The detector comprises a light transmitter and a light receiver which are installed at a distance between 5m and 100m from each other. It detects reduction in the light reaching the receiver due to obscuration of the beam by smoke and transmits a fire signal to a control panel. Fig.3 is a block diagram of the projected beam type smoke detector.

3) Functions

a. Sensitivity setting

The smoke sensitivity of the detector can be set to a predetermined value by setting the sensitivity switch to the corresponding sensitivity depending upon the monitoring distance between 5m and 100m. (Table 1)

b. Sensitivity compensation

The detector has a compensation function to avoid any change in the smoke sensitivity until the light reaching the receiver is reduced to about 50% of the initial light intensity due to contamination of the lenses of the light transmitter and the light receiver or disalignment of the beam caused over an extend period.

c. Trouble alarm

A trouble alarm is initiated to a control panel at the time the received light reaches 50% of the initial light intensity due to open in the detector power supply line, momentary interruption of the beam or contamination of the lenses of the light transmitter and the light receiver.

d. Remote operation test

The operation test of the detector can be carried out by means of the test switch provided on the control panel or close to the detector.

e. Indications

The detector gives a fire alarm indication, a trouble indication, a power-on indication and a remote operation test indication by means of LEDs.

(2) Flame detectors

With adoption of technical standards for flame detectors responding to radiant energy from flame in the Ministerial Ordinance of Fire Service Law of Japan, there has been increasing use of this type of detector for fire monitoring in the atrium space in recent years. The flame detectors are suited for early detection of a small flame occurring close to the floor surface of the atrium. They are roughly classified into the ultraviolet type flame detector and the infrared type flame detector which respectively detect ultraviolet and infrared radiation from flames. A flame detector which combines these two detecting principles and makes a fire judgement is also available. In this paper, the authors describe the infrared type flame detector.

1) Design

Flames developing in the course of combustion of substances contain many infrared rays of resonance radiation from carbon dioxide with peak wavelength of 4.3 $\mu$m and fluctuation of frequency within a range of 1~15Hz. The detector receives this wavelength through special optical filters, detects the frequency typical of flames by means of AC selective converter circuit comprising electric bandpass filters and sends a fire signal to a control panel. Fig.2 shows spectral distribution of different lights from flames. Fig.3 is a block diagram of the detector.

2) Functions

a. Sensitivity

The detector detects an n-heptane fire in a vessel of 1m$^2$ within 30 seconds.

b. Angle of view and monitoring distance

The monitoring ditance is determined for every 5° angle of view. As shown in Fig.4 the detector has monitoring distances of 20m in the front, 13m in the direction of 50° on both sides of the front, and a conical monitoring range with maximum 100 ° angle of view.

c. Indication

On operation of the detector, the response lamp lights up.

### (3) Fire scanning device

This device has come to be used recently for fire monitoring in large spaces such as a dome stadium. By converting the heat radiation energy from a fire to an electrical signal and determining its level, the device pinpoints the fire source and provides a fire extinguishing system such as a water cannon with information on the fire point location. The detector employs a method of locating a fire point by two-dimensional thermal image and is capable of monitoring a wide plane at a time.

#### 1) Design

This device comprises an infrared image type fire detector and a control panel. The infrared image type fire detector uses an infrared camera and is equipped with an optical scanning means for two-dimensional detection of a fire. The detector is installed on a motor-driven swivel base, which, repeatedly rotates 180 ° on both sides in about 25 seconds in normal monitoring state. Fig.7 is a block diagram of the fire scanning device. Fig.8 shows the design of the infrared image type fire detector.

#### 2) Functions

##### a. Sensitivities

The detector can be set to the following sensitivity levels.

- High sensitivity level … a level at which n-heptane fire in a vessel of $0.5m^2$ is to be detected at a distance of 200m.
- Low sensitivity lebel … a level at which n-heptane fire in a vessel of $1m^2$ is to be detected at a distance of 200m.

##### b. Monitoring for plural fires

The device is capable of continuing its monitoring for other fire sources after it has initiated a fire alarm.

##### c. Trouble alarm

A trouble alarm is initiated to a control panel on the part of the fire extinguishing system in case of troubles such as malfunction of any of the equipment and transmission error.

##### d. Remote operation test

The operation test of the fire scanning device can be carried out by means of the test switch on the control panel for the fire extinguishing system.

## 2. Reference of installations

### (1) Edo Tokyo Museum

Edo Tokyo museum is a 7-storey building with 1 basement floor, and a total floor area of $45,000m^2$ . It has a unique design like a sky museum with an exhibition hall, storerooms, and a restaurant in the upper floors; conference rooms, multi-purpose halls and an administration office in the lower floors; and a various event space open to the air in the intermediate level. The exhibition hall situated on the upper part is supported by four pillars at a height exceeding 30m from the ground and forms a large atrium type space with a floor space of 12,000m $^2$ and a maximum ceiling height of 26m so that full scale large items can be exhibited.

For early fire detection the projected beam type smoke detector with a monitoring destance of 50m has been installed in the large space of the exhibition hall, and flame detectors whose sensitivity is not influenced by air current have been installed in the event space open to the air.

(2) Fakuoka dome

Fukuoka dome is a giant 7-storey building with a total floor area of 176,000m$^2$ . It has an appearance of a cylindrical building which closely resembles the colosseum in the ancient Roman times and is covered with a hemispherical roof. It also has an outside diameter of 222m, an inside diameter of 200m and a height of 70m from the arena floor surface to the top of the roof, which form a large scale space. A typical feature of Fukuoka dome is that it can flexibly be adapted to seasons and weather because the roof can be opened and closed. Therefore, besides its use as a baseball stadium, it can be used for multiple purposes such as concert hall having a maximum seating capacity of 50,000 audiences, exhibitions, assemblies etc. This arena space is monitored by means of the fire scanning device. The infrared image type fire detector has been installed at the highest position of the cylindrical part of the dome, i.e. at a height of 31m from the ground and monitors the entire area of the arena of 200m in diameter by horizontally scanning the area at all times. For monitoring the non-supervised area directly below this fire detector, the flame de tectors have been installed. The fire scanning device is linked with a water cannon extinguishing system which automatically directs the cannon toward the fire point and controls the direction and pattern of water discharge to effectively extinguish the fire with the fire alarm and information on location of the fire received from the fire scanning device.

3. Conclusion

The authors have described the actual state of fire detection in atrium buildings in Japan. With advance of building-construction techniques, it is assumed that the forms of atria will be more diversified in the future. Under the circumstances we must promote development of new fire protection technologies for atrium buidings which take account of not only fire detection but also its effective combination with fire extinguishing means. Since the atrium space would have more different construction from the ordinary building space, it is also important, when discussing the fire protection for atrium buildings, to establish an organic cooperative system with ventilation system and other associated building management systems in each individual case rather than attempting to deal with this matter by fire protection systems alone. Therefore, it will be an important theme to be discussed in the future in an endeavor to find a way to collectively use all these systems on the basis of prompt and appropriate judgement of the situations in the premises.

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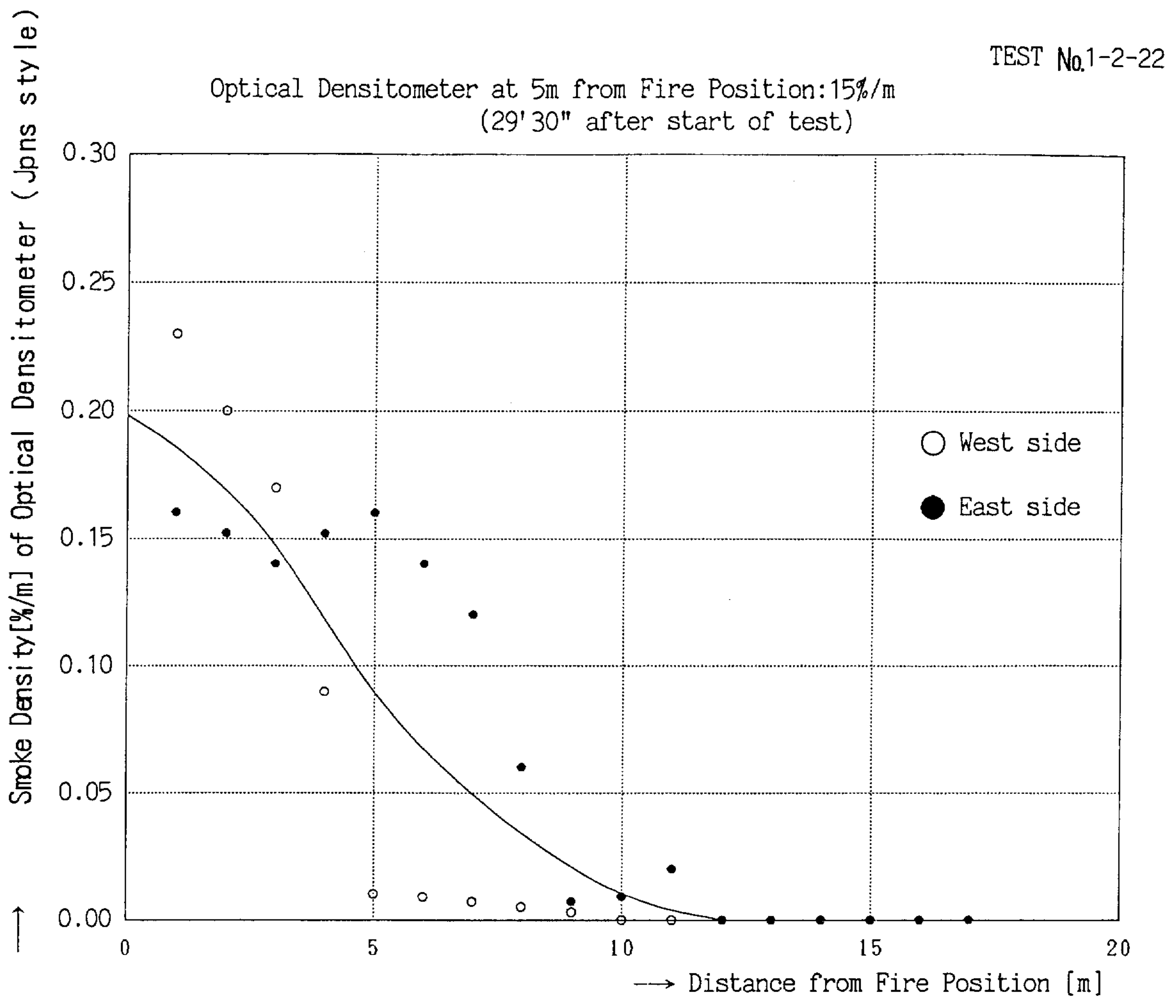


Fig.1 Smoke distribution on ceiling surface during smouldering of wood

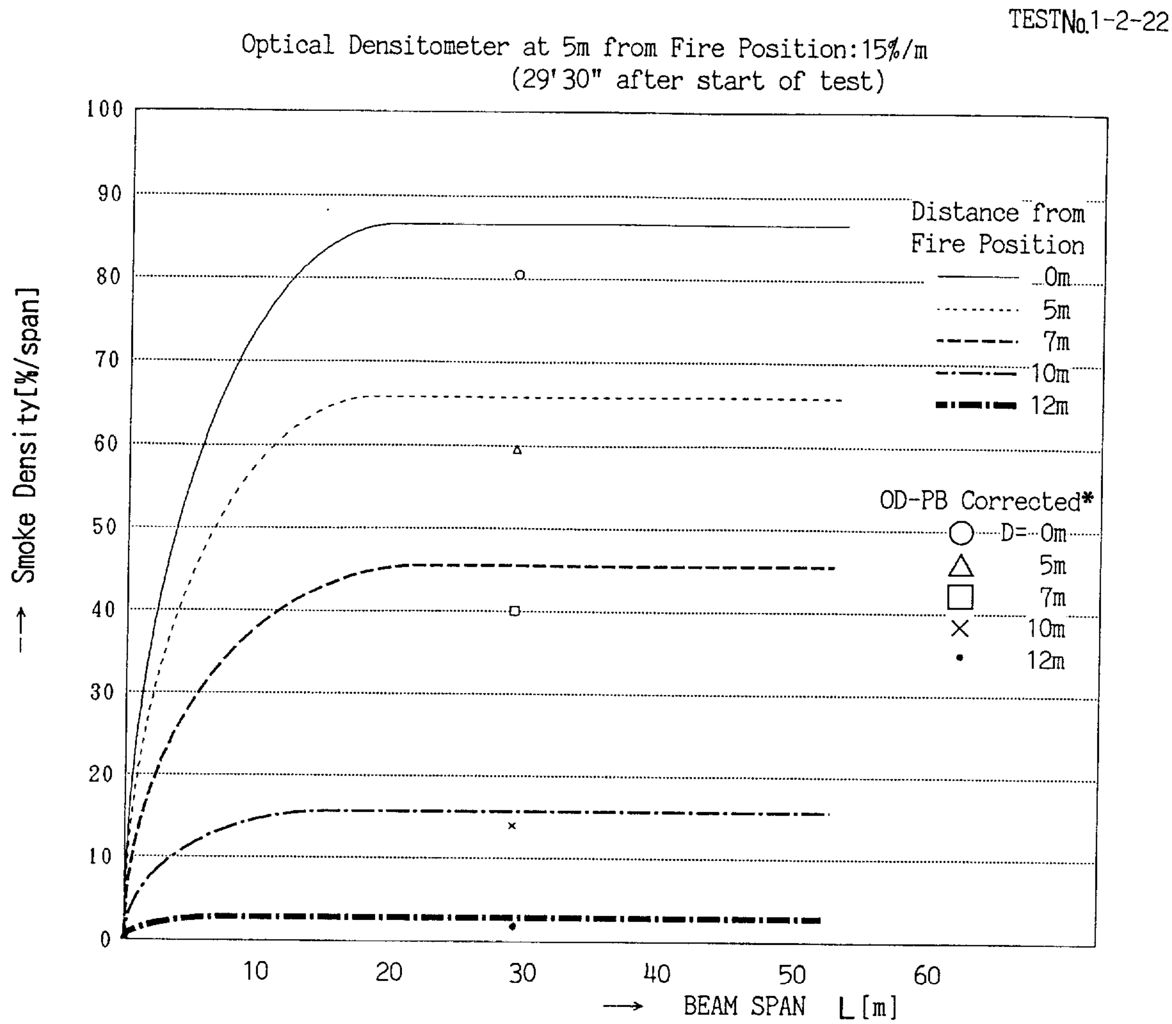


Fig.2 Monitoring distance v.s. Smoke Density of Projected Beam Smoke Detector Expected

*OD-PB Corrected : Opeical Densitometve — Projected Beam Smoke Detector Correction

| Type | Ordinary type, Class 1 | Ordinary type, Class 2 |
|---|---|---|
| Monitoring distance - sensitivity | 5 ~ 20m : 20%<br>20 ~ 40m : 30%<br>40 ~ 100m : 50% | 5 ~ 20m : 30%<br>20 ~ 40m : 50%<br>40 ~ 100m : 70% |

Table 1 Monitoring distances and sensitivities of projected beam type smoke detectors

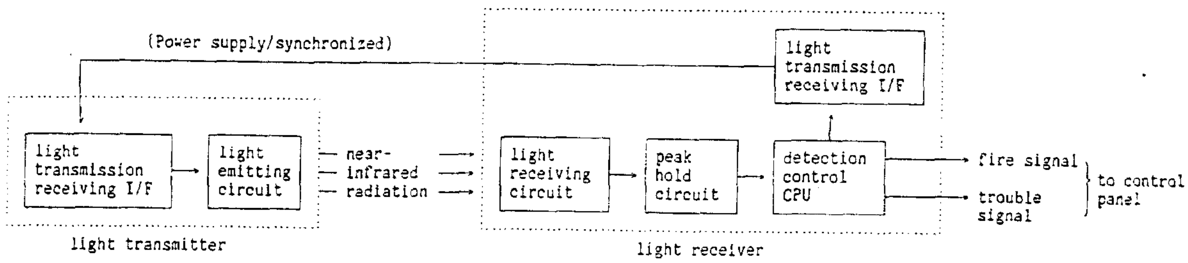


Fig.3 Block diagram of projected beam type smoke detector

(a) candle flame (b) gasoline fire (c) town gas fire
(d) sunlight (e) incandescent lamp (d) Hot substance

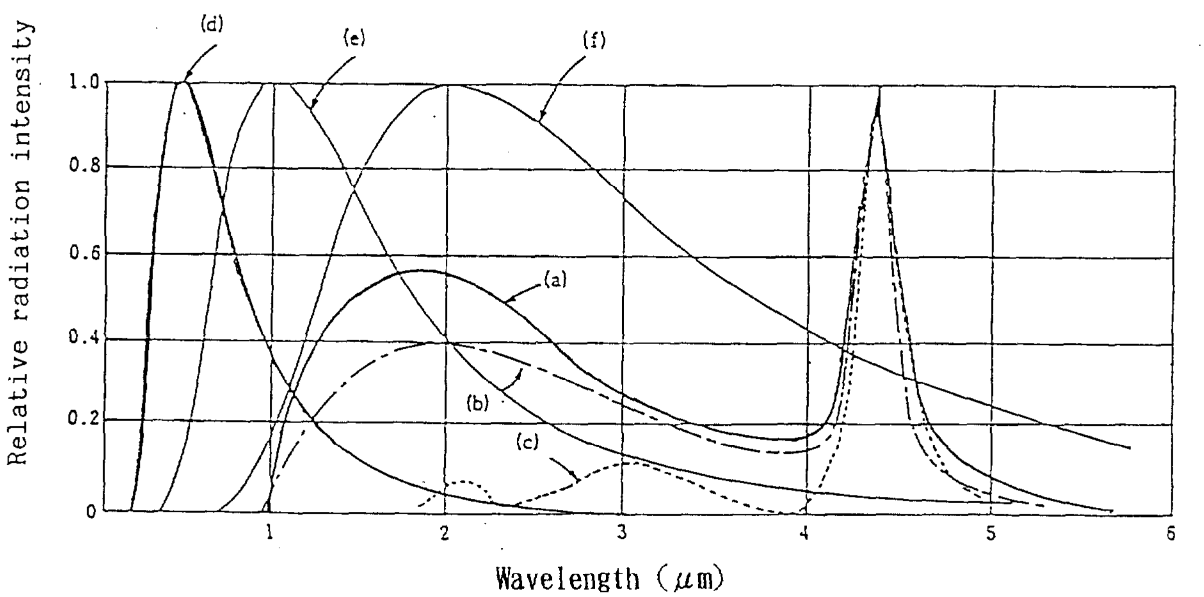


Fig.4 Spectral distribution characteristics

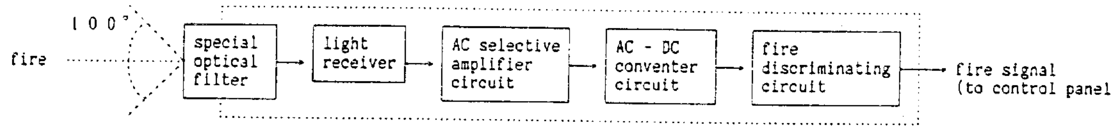


Fig.5 Block diagram of flame detector

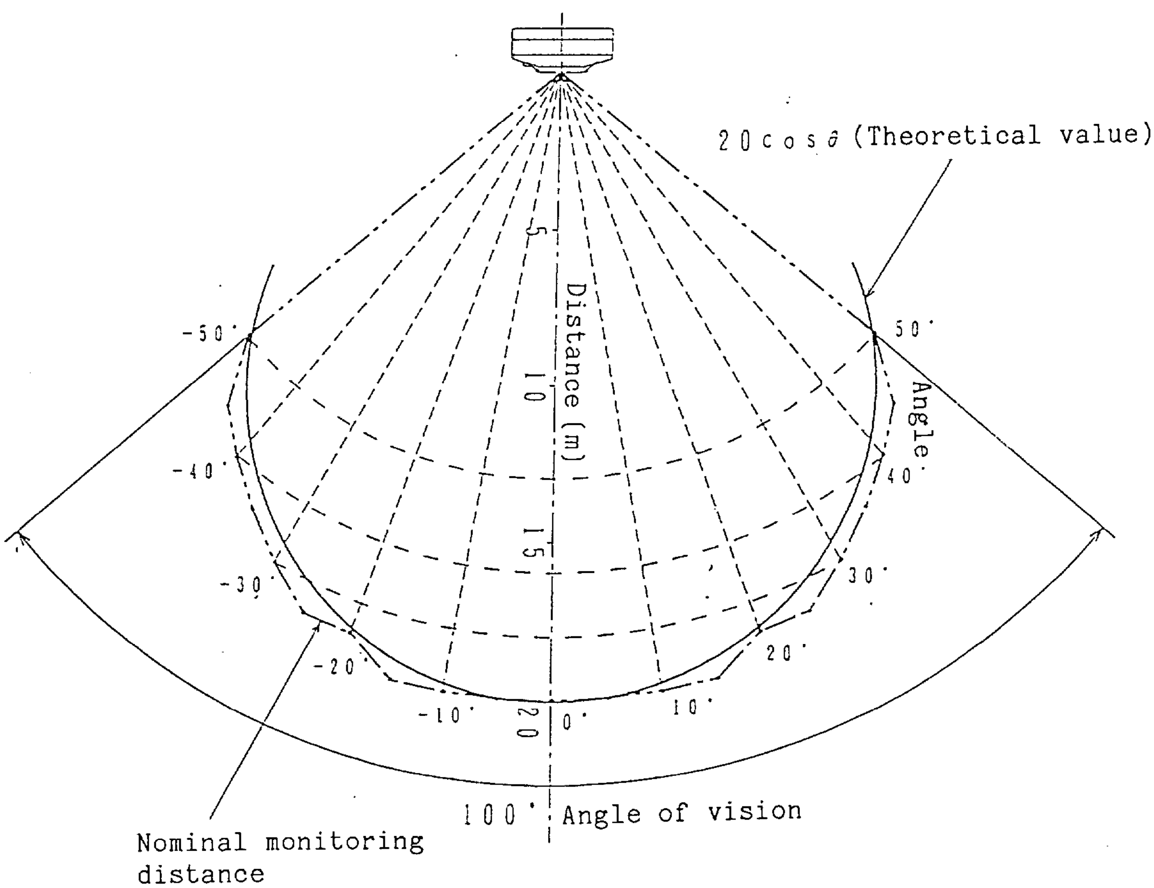


Fig.6 Monitoring range of flame detector

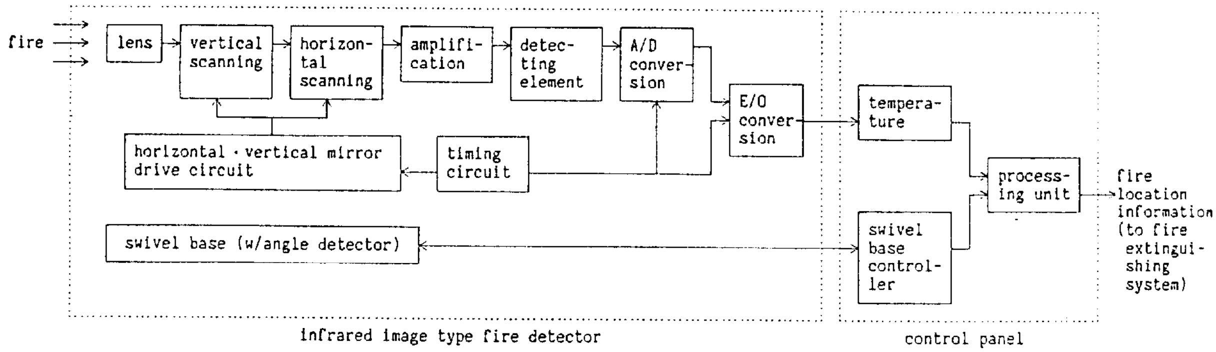


Fig.7 Block diagram of fire scanning device

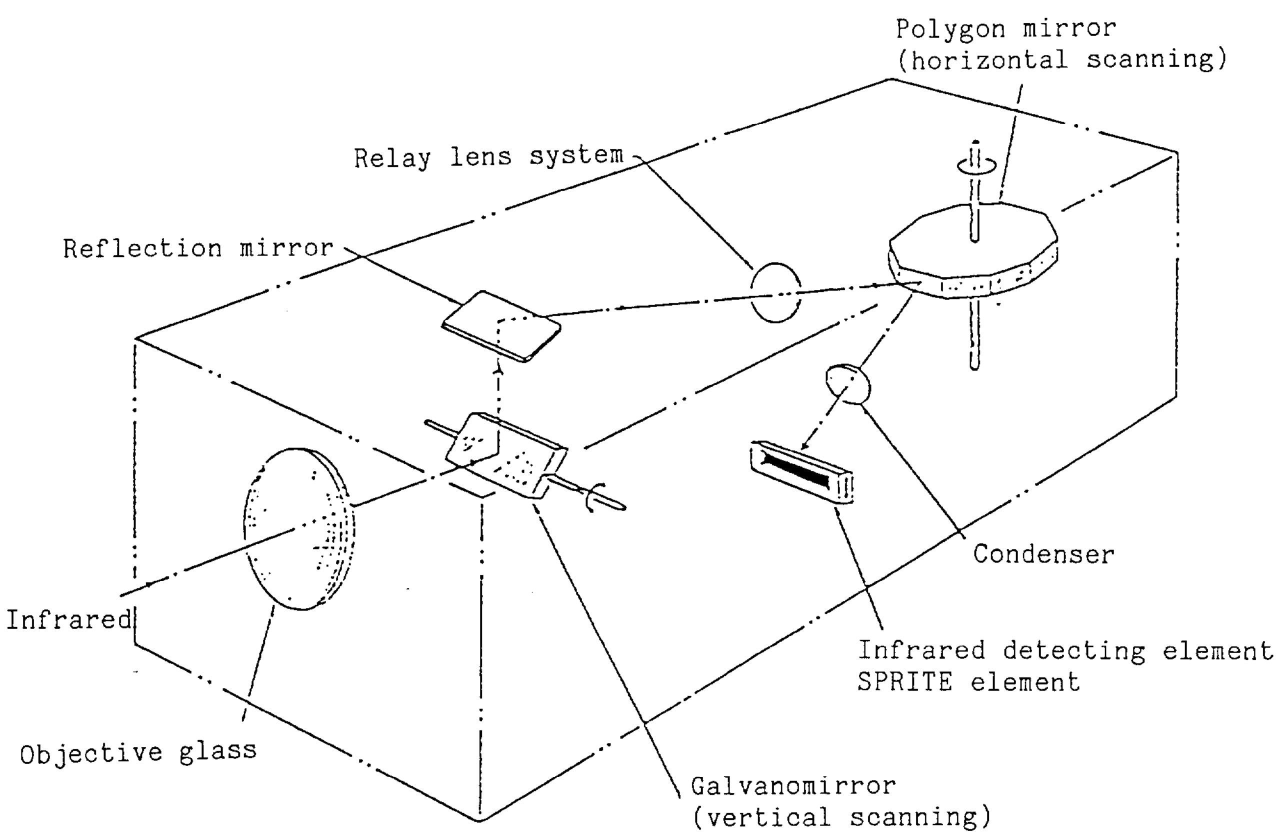


Fig.8 Design of infrared image type fire detector

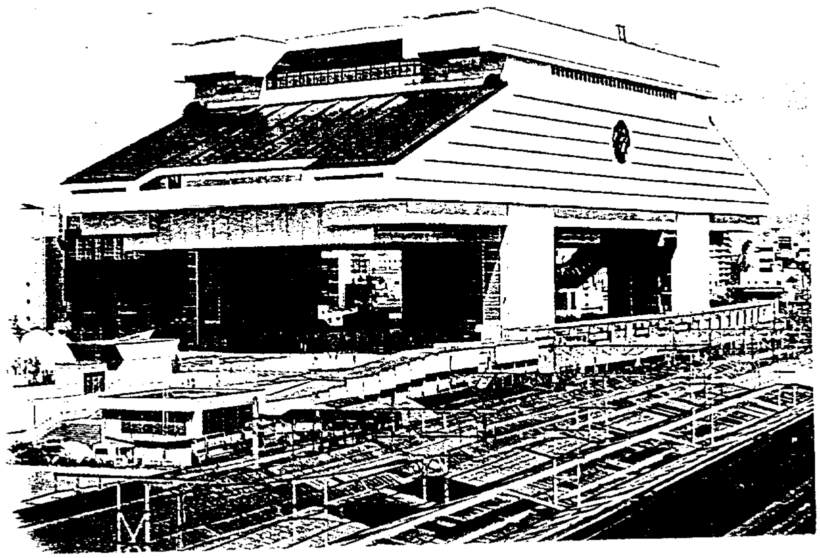

Photo 1　Edo Tokyo Museum

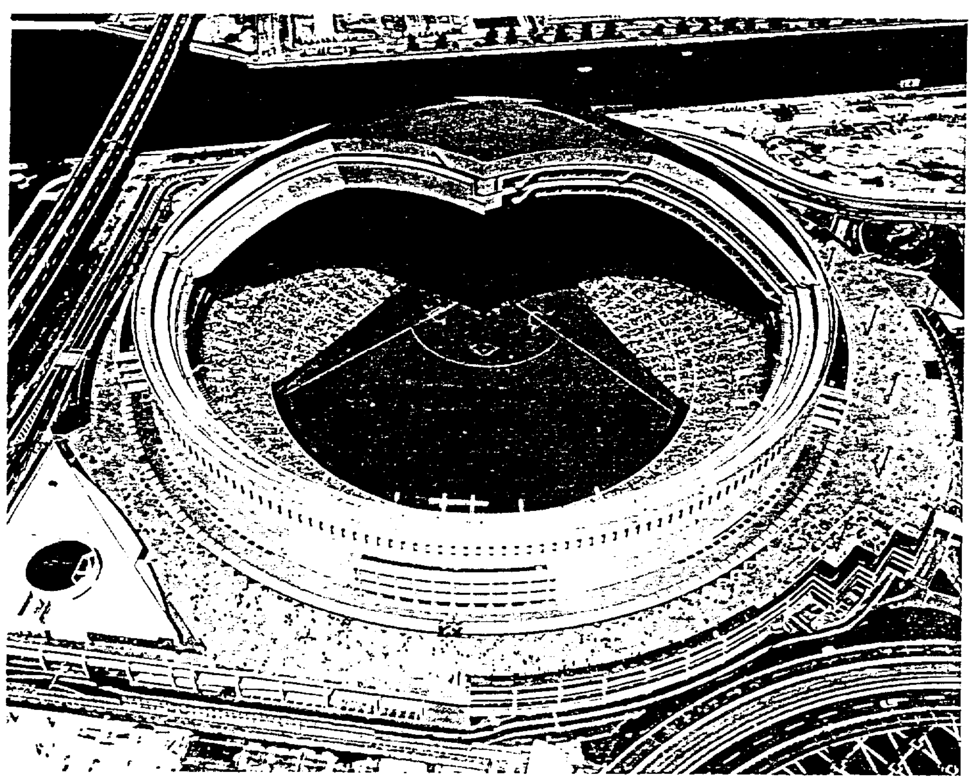

Photo 2　Fukuoka dome

***Discussion***

Walter Jones: Do I understand that this moving camera is currently in use in such buildings?

Joji Kawada: This is the actual camera which is installed in an atrium.